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Abstract

Plate heat exchangers (PHEs) consist of flow channels which are confined by two corrugated walls that are attached in a cross-criss manner; hence, entitled “cross-corrugated channels”. The flow evaporation or condensation inside such geometry generally experiences complex transitions among diverse flow regimes, e.g. bubble flow, slug flow, churn flow and film flow. In contrast with canonical pipe flow, the two phase flow patterns in cross-corrugated channels are not well understood because channel-induced swirl flows add a high degree of complexity to the liquid-vapor interface. In this talk we will present a pioneering computational fluid dynamics (CFD) study of a cross-corrugated channel flow, exploring the two-phase flow pattern and associated phase change phenomenon. The liquid-vapor interface was captured by using the volume of fluid (VOF) method, while the mass transfer during the evaporation was evaluated by the Lee model. Our simulation considers a flow of nearly saturated R245fa (0.5 °C sub-cooling) in a single channel of a plate heat exchanger subject to a uniform heat flux. The computational domain is tailored to be long enough to meet the engineering design length, whereas the width of the domain is reduced by assigning a periodic boundary condition to save computational cost. A set of simulations with 6.2 million nodes were run on a supercomputer. The results indicate that the predicted global heat transfer coefficient and pressure drop are in agreement with experimental data. We note that the flow experiences a sequence of transition from bubble flow to slug flow, and subsequently to churn flow. Moreover, the longitudinal distribution of the heat transfer coefficient is fairly non-uniform, suggesting a strong dependency of the heat transfer coefficient on the local flow regime. For the case we considered, the churn flow regime (with a vapor quality around 0.2) is associated with the highest heat transfer coefficient due to the high velocity fluctuation enhancing the local convective effect. Due to the complexity of the channel geometry, the slug bubbles are irregular in shape, occupy a large portion of the channel space and partially adhere to walls, which decrease the local heat transfer. Overall, the results indicate that an optimal design of a plate heat exchanger could be achieved if the formation of large slug bubbles could be better understood. This, however, requires a better understanding of the fundamental flow patterns associated with the cross-corrugated geometry, and in this context, CFD simulations could play a key role.